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Aerodynamic Roughness and Displacement Height Prediction for Waves

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Abstract

Aerodynamic roughness and displacement heights are important parameters needed to accurately estimate evaporation from free water surfaces. It is evident that evaporation rate is influenced by the mean and turbulent flow properties near the surface of a given body of water. If the aerodynamic roughness can be estimated for the water surface, then the accuracy of predicting evaporation from the free-water surface will be greatly improved.

This study presents an equation to predict displacement height and aerodynamic roughness over water bodies. Wind is the main force, which causes the waves on water surfaces. Surface roughness of water is directly influenced by the velocity of the wind. The equation presented in this study predicts wave heights as a function of wind speed and displacement height and then the aerodynamic roughness as a function of the wave height. This model expands the overall accuracy of evaporation prediction from free-water surfaces.

There are contradictory discussions in the literature about roughness of the water surfaces and between surface roughness and wind speeds. A need exists to clarify the physics and mechanics of the process of evaporation and apply sensible understanding through model verification to better predict evaporation. The model presented in this study is comprised of a set of interactive physically based equations, which relate aerodynamic roughness to surface waves. This Equation when applied to Borelli -Sharif Equation Model was validated by comparing output determined by the model with observed data. Since there are similarities in the process of predicting erosion from beaches, the same equation should be valid for predicting wind erosion of beaches from wind coming off water bodies.

Introduction and development

Soil erosion and evaporation are both surface phenomenon and greatly effected by the wind profile. In order to accurately predict soil erosion and evaporation from water surfaces, the wind velocity profile parameters of displacement height D, and aerodynamic roughness z_o must be accurately determined . Objective of this paper is the overview of the development and evaluation of equations for displacement height and aerodynamic roughness for water surfaces.

Overview and discussion

(Abtew et all., 1989) derived equations for displacement height and aerodynamic roughness for solid objects such as sand grains, soil aggregates, residue or vegetative cover such as trees. Over land surface displacement height and aerodynamic roughness directly related to surface characteristics but over water surfaces there is relation between wind velocity and displacement height and aerodynamic roughness because the wind causes surface roughness to develop as expressed as waves. Darwish 1998, using concept of potential and kinetic energy derived a relationship for wave height and wind velocity. Building on this relationship and by application of (Abtew et al., 1989) relationship for displacement height and aerodynamic roughness a system of equation was developed to predict aerodynamic roughness. Wave height was treated as ridge height in (Abtew et all., 1989)'s equation. Because waves move with wind and the relative velocity between wind and waves is less than between the relative velocity over a solid object (Abtew et al ., 1989)'s equation was modified by slight change adding coefficient.

Results

The wave equations were tested involving variation in wind and fetch length with seven data sets (Darwish, 1998) five of the seven sets with and R^2 of values 0.90 or better. The other two comparisons had values of 0.77 and 0.80. Based on this evidence the equation was accepted as the valid predictor wave height as a function of wind speed. Aerodynamic roughness equation was indirectly verified through prediction of evaporation, R^2 of 0.61 was obtained using Sharif-Borelli model for data collected by Sharif , 1989. Although, R^2 of 0.61 does not sound like a good fit. It was highly significant $\alpha = 0.001$. It improved the prediction of evaporation from R^2 of near 0 to 0.61. Another words it represents a displacement height, and aerodynamic roughness equations derived accounted for 61 % increase in the observed variance. It should be noted that the measured data was for a daily bases which is difficult to measure. Therefore the observed R^2 of 0.61 represents significant improvement in prediction of evaporation. Based on this evidence the aerodynamic roughness equation was also accepted as a valid predictor of aerodynamic roughness for water bodies. It should be noted based on personal communications with Dr.Wossenu Abtew, he too has learned that his aerodynamic roughness equation was applied for ridges as reasonable prediction for aerodynamic roughness over water surfaces.

Conclusions

Aerodynamic roughness of the water surface can be determined from the wave heights, if the wave heights can be predicted from the wind velocity measurements. Equations tested in this study provides a relation between wind velocity and wave heights therefore can be used for more accurate prediction of evaporation over water bodies.

References

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